BRIEF DESCRIPTION OF THE DRAWINGS

A full understanding of the present invention will be obtained from the detailed description of the preferred embodiment presented hereinbelow, and the accompanying drawings, which are given by way of illustration only and are not intended to limit the present invention, and wherein:

figure 1 illustrates a typical seismic operation;

figure 2 illustrates a well logging operation;

figures 3 and 4 illustrate the seismic signals which are received by the geophones of figure 1;

figure 5 illustrates how the seismic data output record and the well log data output record combine to represent the "data received";

figure 6 illustrates how the attribute data sets are generated from the data received of figure 5;

figures 7 through 13 illustrate how the attribute data sets are produced from a seismic operation;

figures 14 and 15 illustrate a workstation which stores the seisclass software of the present invention;

figure 16 illustrates a basic flowchart representing the overall functional operation of the present invention when the seisclass software of the present invention is executed;

figures 17 through 21 illustrate how the class data set of the present invention is produced when the attribute data sets of figure 13 are used by the workstation processor of figure 14 to produce the class data set of the present invention during execution of the seisclass software of the present invention;

figure 22 illustrates a more detailed construction of the seisclass software of the present invention including an Unsupervised seisclass software and a Supervised seisclass software;

figure 23 illustrates a block diagram depicting the Unsupervised seisclass software of the present invention of figure 22;

figure 24 illustrates the principles behind the "auxiliary results QC measures" code 142 of figure 23;

figure 25 illustrates a block diagram depicting the unsupervised classification code 132 of figure 23;

figure 26 illustrates a block diagram and description depicting the apply classification and determine quality indicators code 146 of figure 25;

figure 27 illustrates the functional operation of blocks 158, 160, and 162 of figure 26;

figure 28 illustrates the functional operation of blocks 166, 168, and 170 of figure 26;

figure 29 illustrates the functional operation of block 172 of figure 26;

figure 30 illustrates a block diagram depicting the Supervised seisclass software of the present invention of figure 22;

figure 31 illustrates the various classes which may be selected for the 'classes in use - manually defined class types' of figure 30;

figures 32 through 34 illustrate how one could select and declare training data in connection with the 'training/validation' of figure 30;

figures 35 through 37 illustrate how one could select and declare validation data in connection with the 'training/validation' of figure 30;

figure 38 illustrates a detailed construction of the supervised classification code 186 of figure 30;

figure 39 illustrates a detailed construction of the "training of the classifications" code 208 of figure 38;

figure 40 illustrates the functional operation of blocks 226, 228, and 230 of figure 39;

figure 41 illustrates the functional operation of block 234, 236, and 238 of figure 39;

figure 42 illustrates the functional operation of the "training of the classifications" block 242 of figure 39;

figure 43 illustrates the functional operation of the "apply the trained classification and determine quality indication" 216 of figure 38;

figure 44 illustrates the functional operation of the "classified result" or “class data set” block 130 of figure 30; and

figure 44A illustrates a 3D cube which includes a plurality of such 'class data sets' corresponding, respectively, to a plurality of subsurfaces in an earth formation.

figure 45 illustrates an unsupervised method of classification, which attempts classification based upon natural clustering of data in attribute space and "supervised" methods which require training samples, in accordance with a preferred embodiment of the present invention.

figure 46 illustrates horizontal classification using surface attribute grids in accordance with a preferred embodiment of the present invention.

figure 47 illustrates data access vertical classification in accordance with a preferred embodiment of the present invention.

figure 48 illustrates a software architecture depicting a portion of SEISCLASS and CHARISMA versus GEOFRAME in accordance with a preferred embodiment of the present invention.

figure 49 illustrates SEISCLASS windows including the 'Administration Window' adapted for running a classification and data management and the crossplot and the map or section windows adapted for serving as data exploration windows in accordance with a preferred embodiment of the present invention.

figure 50 illustrates window usage depending upon classification domain, in accordance with a preferred embodiment of the present invention.

figure 51 is a block diagram that illustrates the flow of data types between applications that are relevant to SeisClass when horizontal classification is used in a preferred embodiment of the present invention.

figure 52 is a block diagram that illustrates the flow of data when SEISCLASS is used with GEOFRAME 3.0 including the interaction of CPSLINK, CPS 3, and IESX with SeisClass in a preferred embodiment of the present invention.

figure 53a illustrates an unsupervised method of classification, specifically K-Means Clustering, used in accordance with a preferred embodiment of the present invention.

figure 53b illustrates an unsupervised method of classification, specifically Competitive Learning, used in accordance with a preferred embodiment of the present invention.

figure 54 illustrates a supervised method of classification, specifically Back-Error Propagation method involving a 'single layer perceptron' representational power, used in accordance with a preferred embodiment of the present invention.

figure 55 illustrates class representations including a class definition repository having an additional translation layer in accordance with a preferred embodiment of the present invention.

figure 56 illustrates method catalogs and their relationship to other SEISCLASS entities, in accordance with a preferred embodiment of the present invention.

figure 57 illustrates grouping of SEISCLASS input attributes including the grouping of input attribute representations, corresponding well derived attributes to individual attribute representations, and

training/validation representations in accordance with a preferred embodiment of the present invention.

figure 58 illustrates grouping of training/validation data in accordance with a preferred embodiment of the present invention.

figure 59 illustrates General Set entity relations in accordance with a preferred embodiment of the present invention.

figure 60 illustrates Well Attribute Reference in connection with Well Binding and, specifically, which intermediate objects have to be added in order to branch from "well_attr_ref" to logs or constants having continuous or discrete representations, in accordance with a preferred embodiment of the present invention.

figure 61 illustrates classification run entity relations and, in particular, the presentation of the various links to other data entities organized counterclockwise starting from 'model entity' at the top of this figure, in accordance with a preferred embodiment of the present invention.

figure 62 illustrates contexts in SEISCLASS data administration and the data objects associated to a Classification Run Context, in accordance with a preferred embodiment of the present invention.

figure 63 illustrates SEISCLASS Administration main window including two main frames including 'classification runs' and 'active runs' for a preferred embodiment of the present invention.

figure 64 illustrates classification runs hierarchy for a preferred embodiment of the present invention.

figure 65 illustrates information presented for an active run in a preferred embodiment of the present invention.

figure 66 illustrates a message help area dialog of SEISCLASS in a preferred embodiment of the present invention.

figure 67 illustrates a new classification run dialog of SEISCLASS in a preferred embodiment of the present invention.

figure 68 illustrates a dialog for modifying an existing classification run, in accordance with a preferred embodiment of the present invention.

figure 69 illustrates a delete classification run dialog for deleting an existing classification run, in a preferred embodiment of the present invention.

figure 70 illustrates a function pull down menu (Administration) dialog including three sections further including the classification run handling section, the data analysis section, and the report and message window hanging section in accordance with a preferred embodiment of the present invention.

figure 71 illustrates an options pull down menu (Administration) dialog in accordance with a preferred embodiment of the present invention.

figure 72 illustrates a selections pull down menu (Administration) dialog in accordance with a preferred embodiment of the present invention.

figure 73 illustrates a dialog for input attribute set selection allowing for the definition of a collection of attributes to be used with a classification, in accordance with a preferred embodiment of the present invention.

figure 74 illustrates a dialog for attribute selection, in accordance with a preferred embodiment of the present invention.

figure 75 illustrates an attributes in set dialog associated with attribute selection, in accordance with a preferred embodiment of the present invention.

figure 76 illustrates a new attribute set dialog for creation of new input attribute sets, in accordance with a preferred embodiment of the present invention.

figure 77 illustrates a dialog for well supplement selection, in accordance with a preferred embodiment of the present invention.

figure 78 illustrates a dialog for selection by log type, in accordance with a preferred embodiment of the present invention.

figure 79 illustrates a cell context selection frame in accordance with a preferred embodiment of the present invention.

figure 80 illustrates a "Find Empty Cells" dialog including an action button to find empty cells, in accordance with a preferred embodiment of the present invention.

figure 81 illustrates a training/validation set dialog for training/validation set selection allowing the definition of a set of data used with the training or validation step during a 'supervised' classification, in accordance with a preferred embodiment of the present invention.

figure 82 illustrates a current training/validation set frame, in accordance with a preferred embodiment of the present invention.

figure 83 illustrates a training/validation well selection frame for concentrating all functions relating to the 'well supplement', in accordance with a preferred embodiment of the present invention.

figure 84 illustrates a current well context frame that indicates a well in context and allows an alternative well selection, in accordance with a preferred embodiment of the present invention.

figure 85 illustrates a new training/validation set dialog enabling the creation of new training/validation sets, in accordance with a preferred embodiment of the present invention.

figure 86a illustrates a "Classes in Use" dialog for classes in use, Fisher Method, for supervised methods in accordance with a preferred embodiment of the present invention.

figure 86b illustrates a "Classes in Use" dialog for classes in use, Bayesian Method, for supervised methods in accordance with a preferred embodiment of the present invention.

figure 86c illustrates a "Classes in Use" dialog for classes in use, Contextual Bayesian Method, for supervised methods in accordance with a preferred embodiment of the present invention.

figure 87 illustrates a "Classes in Use" dialog for classes in use, unsupervised methods, including a Built-in Class Hierarchy for unsupervised methods in accordance with a preferred embodiment of the present invention.

figure 88 illustrates a Bayesian parameters dialog for the Bayesian Method and for the Contextual Bayesian Classification Method, in accordance with a preferred embodiment of the present invention.

figure 89 illustrates a Back Error Propagation Parameters dialog for back error propagation parameters, in accordance with a preferred embodiment of the present invention.

figure 90 illustrates a Competitive Learning Parameters dialog for Competitive Learning parameters, in accordance with a preferred embodiment of the present invention.

figure 91 illustrates a K-Means Clustering Parameters dialog for K-Means clustering parameters, in accordance with a preferred embodiment of the present invention.

figure 92 illustrates a Save Results Selection dialog for the selection/ de-selection of the output data, in accordance with a preferred embodiment of the present invention.

figure 93 illustrates an “active run sensitivity after save results” frame, in accordance with a preferred embodiment of the present invention.

figure 94 illustrates a class library dialog, including a ‘Class Hierarchy’ top frame serving as a navigation and selection device, in accordance with a preferred embodiment of the present invention.

figure 95 illustrates a new class definition dialog, where a ‘class name’ can be typed into an editable text field, in accordance with a preferred embodiment of the present invention.

figure 96 illustrates a SEISCLASS crossplot window layout including a histogram, an active crossplot frame, and passive crossplot frames, in accordance with a preferred embodiment of the present invention.

figure 97 illustrates a crossplot datapoint Pixmaps frame including selection, training, and validation in accordance with a preferred embodiment of the present invention.

figure 98 illustrates a crossplot functions pull-down window, including viewpoint manipulations, editing functions, and projection manipulations, in accordance with a preferred embodiment of the present invention.

figure 99 illustrates a "rotate interaction concept", in accordance with a preferred embodiment of the present invention.

figure 100 illustrates a reset projection function in accordance with a preferred embodiment of the present invention.

figure 101 illustrates a crossplot training/validation edit dialog for collecting all functional controls and context selections required for editing training/validation data in crossplot frames, in accordance with a preferred embodiment of the present invention.

figure 102 illustrates a multiframe dialog which is available via the 'crossplot options' menu bar in accordance with a preferred embodiment of the present invention.

figure 103 illustrates a crossplot display options dialog for collecting all crossplot display option selections, in accordance with a preferred embodiment of the present invention.

figure 104 illustrates a histogram display options dialog for histogram display options available via a 'crossplot options' menu bar pull down in accordance with a preferred embodiment of the present invention.

figure 105 illustrates an information area customization dialog for information area customization containing crossplot relevant items, in accordance with a preferred embodiment of the present invention.

figure 106 illustrates a dialog for cursor tracking in accordance with a preferred embodiment of the present invention.

figure 107 illustrates a tour options dialog which offers a slider selection for the rotation increment used for the start tour function in accordance with a preferred embodiment of the present invention.

figure 108 illustrates a data visibility dialog allowing the selection of attributes defining the coordinate system and a data visibility selection according to category in accordance with a preferred embodiment of the present invention.

figure 109 illustrates a histogram data visibility dialog which defines 'data visibility' for crossplot frames in accordance with a preferred embodiment of the present invention.

figure 110 illustrates an external map display control involving a dedicated display function in accordance with a preferred embodiment of the present invention.

figure 111 illustrates a "Discrete Colour Table Example" including a class grid display adapted for mapping into a discrete class color look-up table in accordance with a preferred embodiment of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A full understanding of the present invention will be obtained from the detailed description of the preferred embodiment presented hereinbelow, and the accompanying drawings, which are given by way of illustration only and are not intended to limit the present invention, and wherein:

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figures 7 through 13 illustrate how the attribute data sets are produced from a seismic operation;

figures 14 and 15 illustrate a workstation which stores the seisclass software of the present invention;

figure 16 illustrates a basic flowchart representing the overall functional operation of the present invention when the seisclass software of the present invention is executed;

figures 17 through 21 illustrate how the class data set of the present invention is produced when the attribute data sets of figure 13 are used by the workstation processor of figure 14 to produce the class data set of the present invention during execution of the seisclass software of the present invention;

figure 22 illustrates a more detailed construction of the seisclass software of the present invention including an Unsupervised seisclass software and a Supervised seisclass software;

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figure 25 illustrates a block diagram depicting the unsupervised classification code 132 of figure 23;

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figure 27 illustrates the functional operation of blocks 158, 160, and 162 of figure 26;

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figure 30 illustrates a block diagram depicting the Supervised seisclass software of the present invention of figure 22;

figure 31 illustrates the various classes which may be selected for the 'classes in use - manually defined class types' of figure 30;

figures 32 through 34 illustrate how one could select and declare training data in connection with the 'training/validation' of figure 30;

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figure 44 illustrates the functional operation of the "classified result" or “class data set” block 130 of figure 30; and

figure 44A illustrates a 3D cube which includes a plurality of such 'class data sets' corresponding, respectively, to a plurality of subsurfaces in an earth formation.

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figure 57 illustrates grouping of SEISCLASS input attributes including the grouping of input attribute representations, corresponding well derived attributes to individual attribute representations, and

training/validation representations in accordance with a preferred embodiment of the present invention.

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figure 59 illustrates General Set entity relations in accordance with a preferred embodiment of the present invention.

figure 60 illustrates Well Attribute Reference in connection with Well Binding and, specifically, which intermediate objects have to be added in order to branch from "well_attr_ref" to logs or constants having continuous or discrete representations, in accordance with a preferred embodiment of the present invention.

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figure 69 illustrates a delete classification run dialog for deleting an existing classification run, in a preferred embodiment of the present invention.

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figure 86c illustrates a "Classes in Use" dialog for classes in use, Contextual Bayesian Method, for supervised methods in accordance with a preferred embodiment of the present invention.

figure 87 illustrates a "Classes in Use" dialog for classes in use, unsupervised methods, including a Built-in Class Hierarchy for unsupervised methods in accordance with a preferred embodiment of the present invention.

figure 88 illustrates a Bayesian parameters dialog for the Bayesian Method and for the Contextual Bayesian Classification Method, in accordance with a preferred embodiment of the present invention.

figure 89 illustrates a Back Error Propagation Parameters dialog for back error propagation parameters, in accordance with a preferred embodiment of the present invention.

figure 90 illustrates a Competitive Learning Parameters dialog for Competitive Learning parameters, in accordance with a preferred embodiment of the present invention.

figure 91 illustrates a K-Means Clustering Parameters dialog for K-Means clustering parameters, in accordance with a preferred embodiment of the present invention.

figure 92 illustrates a Save Results Selection dialog for the selection/ de-selection of the output data, in accordance with a preferred embodiment of the present invention.

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figure 95 illustrates a new class definition dialog, where a ‘class name’ can be typed into an editable text field, in accordance with a preferred embodiment of the present invention.

figure 96 illustrates a SEISCLASS crossplot window layout including a histogram, an active crossplot frame, and passive crossplot frames, in accordance with a preferred embodiment of the present invention.

figure 97 illustrates a crossplot datapoint Pixmaps frame including selection, training, and validation in accordance with a preferred embodiment of the present invention.

figure 98 illustrates a crossplot functions pull-down window, including viewpoint manipulations, editing functions, and projection manipulations, in accordance with a preferred embodiment of the present invention.

figure 99 illustrates a "rotate interaction concept", in accordance with a preferred embodiment of the present invention.

figure 100 illustrates a reset projection function in accordance with a preferred embodiment of the present invention.

figure 101 illustrates a crossplot training/validation edit dialog for collecting all functional controls and context selections required for editing training/validation data in crossplot frames, in accordance with a preferred embodiment of the present invention.

figure 102 illustrates a multiframe dialog which is available via the 'crossplot options' menu bar in accordance with a preferred embodiment of the present invention.

figure 103 illustrates a crossplot display options dialog for collecting all crossplot display option selections, in accordance with a preferred embodiment of the present invention.

figure 104 illustrates a histogram display options dialog for histogram display options available via a 'crossplot options' menu bar pull down in accordance with a preferred embodiment of the present invention.

figure 105 illustrates an information area customization dialog for information area customization containing crossplot relevant items, in accordance with a preferred embodiment of the present invention.

figure 106 illustrates a dialog for cursor tracking in accordance with a preferred embodiment of the present invention.

figure 107 illustrates a tour options dialog which offers a slider selection for the rotation increment used for the start tour function in accordance with a preferred embodiment of the present invention.

figure 108 illustrates a data visibility dialog allowing the selection of attributes defining the coordinate system and a data visibility selection according to category in accordance with a preferred embodiment of the present invention.

figure 109 illustrates a histogram data visibility dialog which defines 'data visibility' for crossplot frames in accordance with a preferred embodiment of the present invention.

figure 110 illustrates an external map display control involving a dedicated display function in accordance with a preferred embodiment of the present invention.

figure 111 illustrates a "Discrete Colour Table Example" including a class grid display adapted for mapping into a discrete class color look-up table in accordance with a preferred embodiment of the present invention.

Refer to Figure 19.

2.2.1.2 Competitive Learning Method

Competitive Learning is usually labeled as a neural network paradigm and considered as an alternative approach to statistically motivated methods like K-Means Clustering. However, one may as well view the algorithm as an extended variation of K-Means Clustering. Comparative studies with Competitive Learning have yield good results in several fields.

Like K-Means Clustering, Competitive Learning does not make any assumptions about the distribution of the data. The number of classes is specified a priori. The method itself controls the initial cluster center distribution. During training, attribute vectors are iteratively presented and the cluster vector that is closest to the attribute vector is updated so that it is even more likely to win the next time the particular attribute vector is presented. Training is stopped after a certain number of iterations, or when the cluster vector only changes marginally.

"Advantages"

- produces same results for identical initial user-supplied conditions
- no assumptions about underlying data and data distribution

"Disadvantages"

- method does not converge in general, but this is compensated with weight decay
- slow training of network
- the theoretical foundation is not as solid as classical statistical methods

Refer to Figure 53a and 53b.